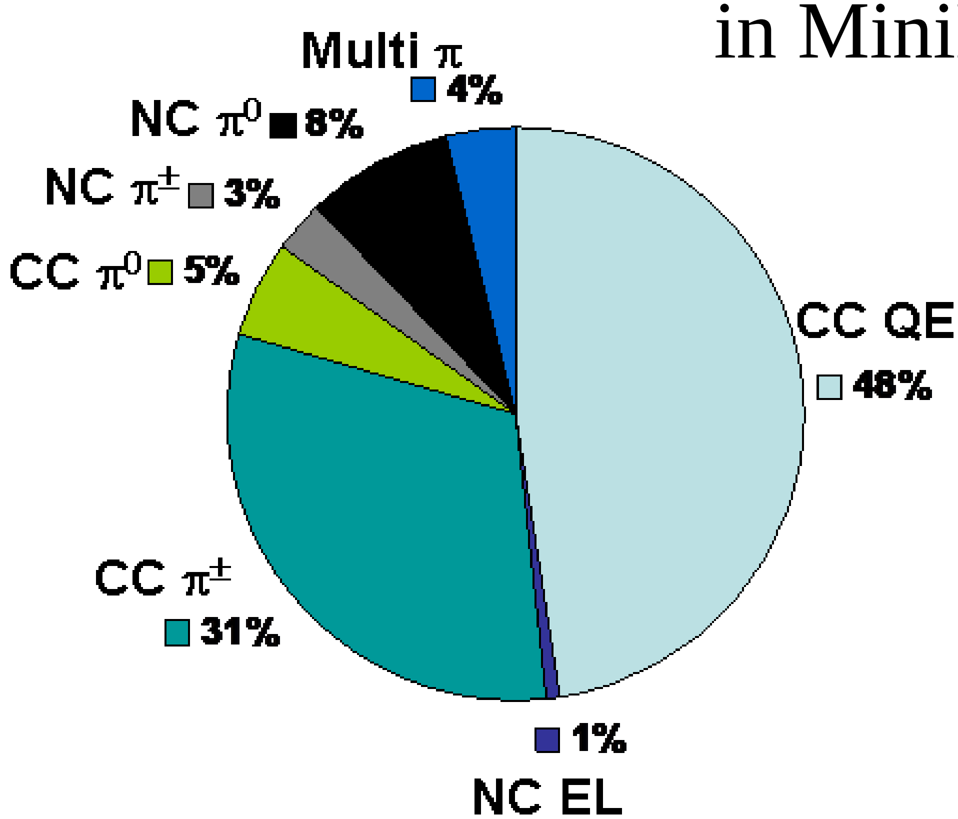
Charged Current Neutrino Interactions in MiniBooNE



Janet Conrad,
Columbia University
PANIC 2005

This talk is brought to you by...

Especially
the members of the
MiniBooNE Cross Sections
Group

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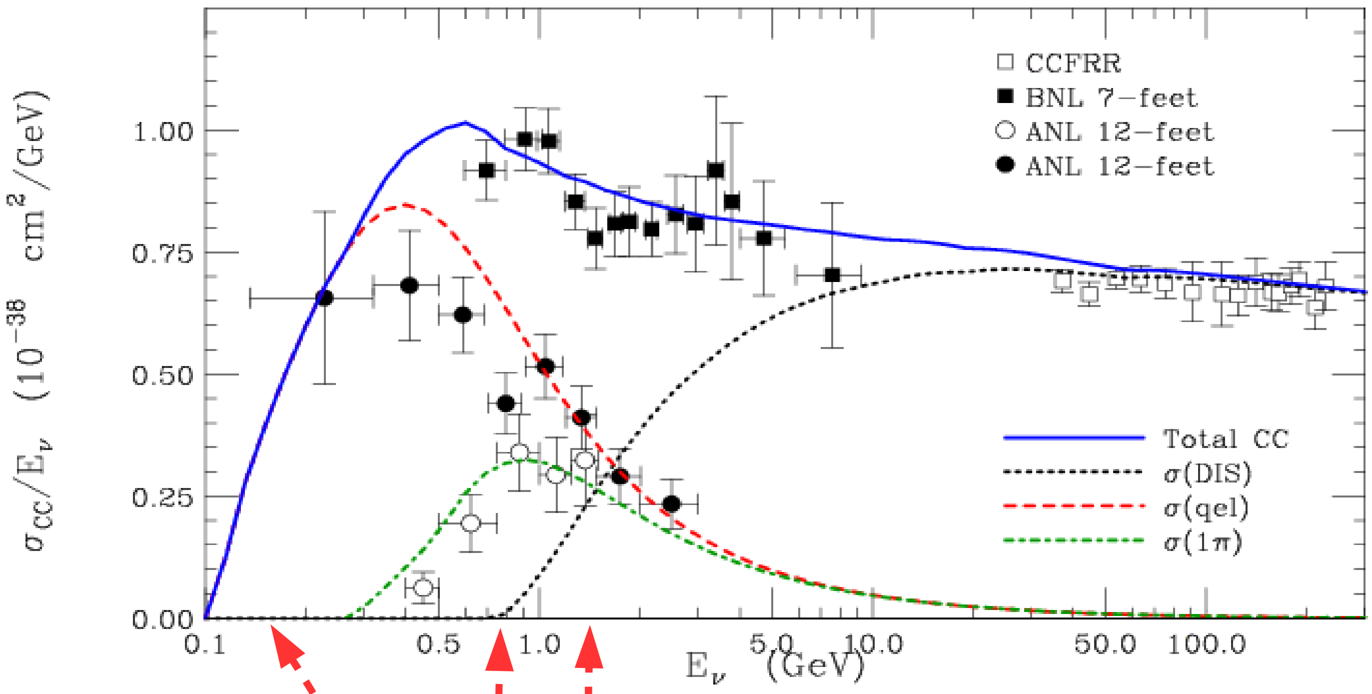
P. Lipari, Nucl. Phys. Proc. Suppl. 112, 274 (2002) (NuInt01)



Why Measure Cross Sections?

Super-K atmospheric νs

Inherent interest in understanding

Nuclear effects

Coherent scattering models

Surprises (and I'll show you one!)

Range of NuMI Possibilities (MINERνA)

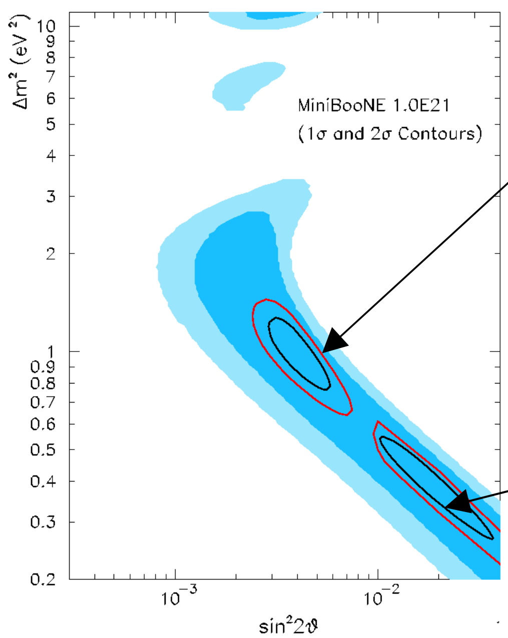
Value to other measurements:

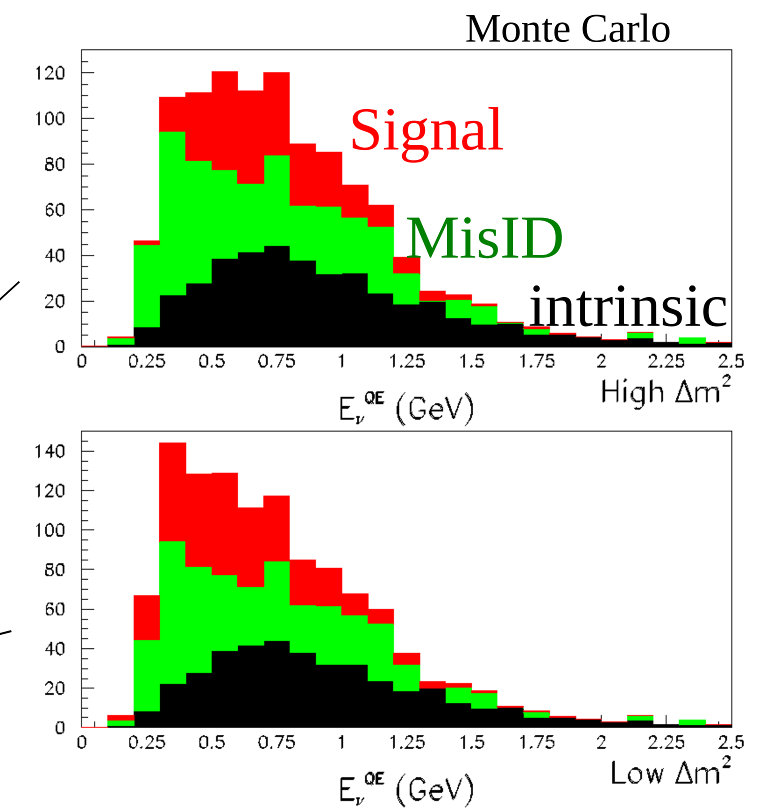
especially oscillation experiments...

Value to the MiniBooNE Oscillation Measurement

To see a $\nu_\mu \rightarrow \nu_e$ signal
(see Zelimir Djurcic's talk)

We need to understand rates and backgrounds!

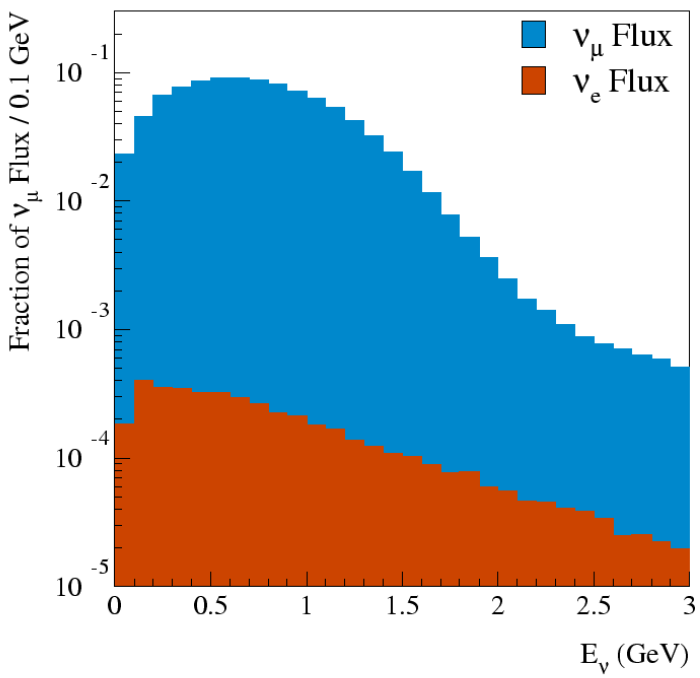




The energy range available in MiniBooNE leads two main types of

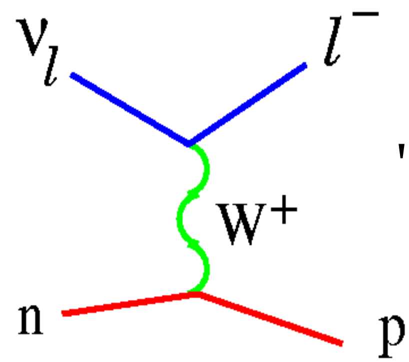
Charged Current Interactions

(Beam produced by
8 GeV p on Be)



Bob Nelson will tell you
more about the beam!

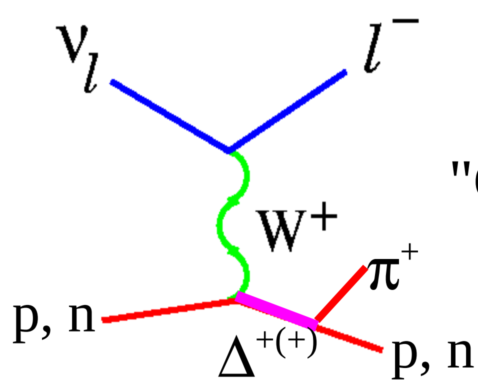
48%



"CCQE"

of all
events

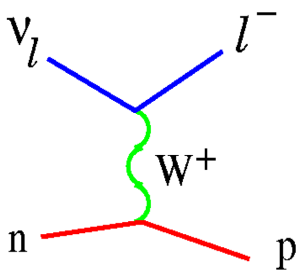
31%



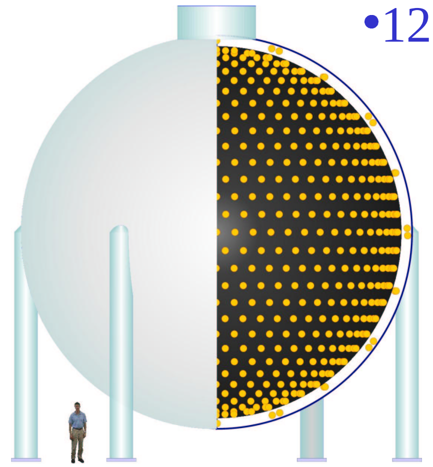
"CCPI+"

(Rates predicted by the
"Nuance" MC generator)

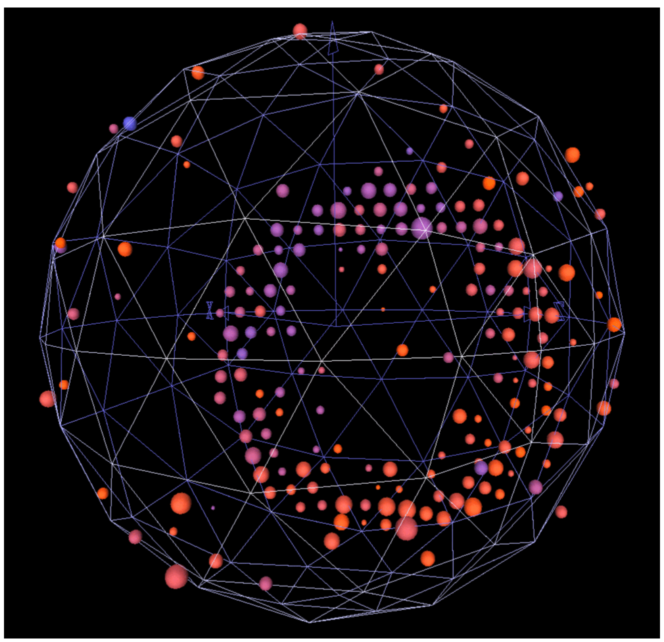
CCQE Events in the MiniBooNE Detector



The Detector



- 12 meter diameter sphere
- 950,000 liters of oil
- 1280 inner PMTs
- 240 veto PMTs.
- Cerenkov & Scintillation photons



Select events which have
- a muon above Cerenkov Threshold,
- target debris below Cerenkov Threshold
- and <6 hits in the veto

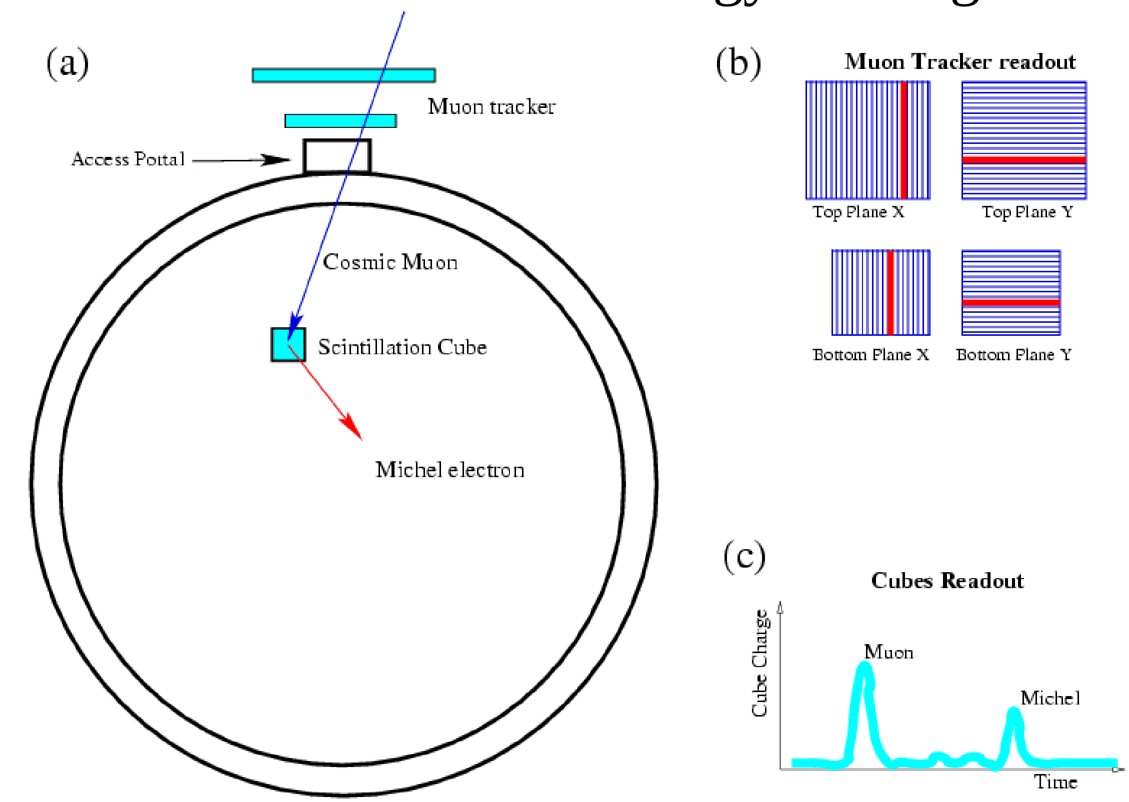
* 88% QE purity

* dominant background: CCPi+ events (π^+ absorbed)

Neutrino energy is reconstructed using the muon energy & angle

$$E_{\nu}^{QE} = \frac{1}{2}\frac{2M_pE_\mu - m_\mu^2}{M_p - E_\mu + \sqrt{(E_\mu^2 - m_\mu^2)}\cos\theta_\mu}$$

We calibrate both muon energy and angle using cosmic rays...

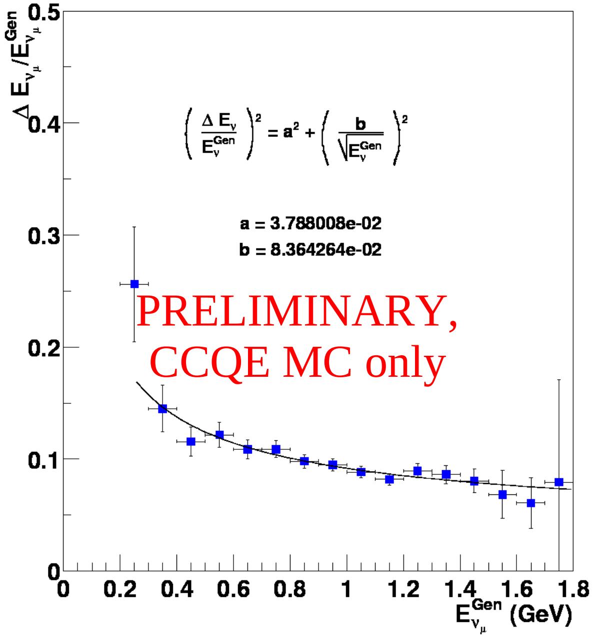


For muons...

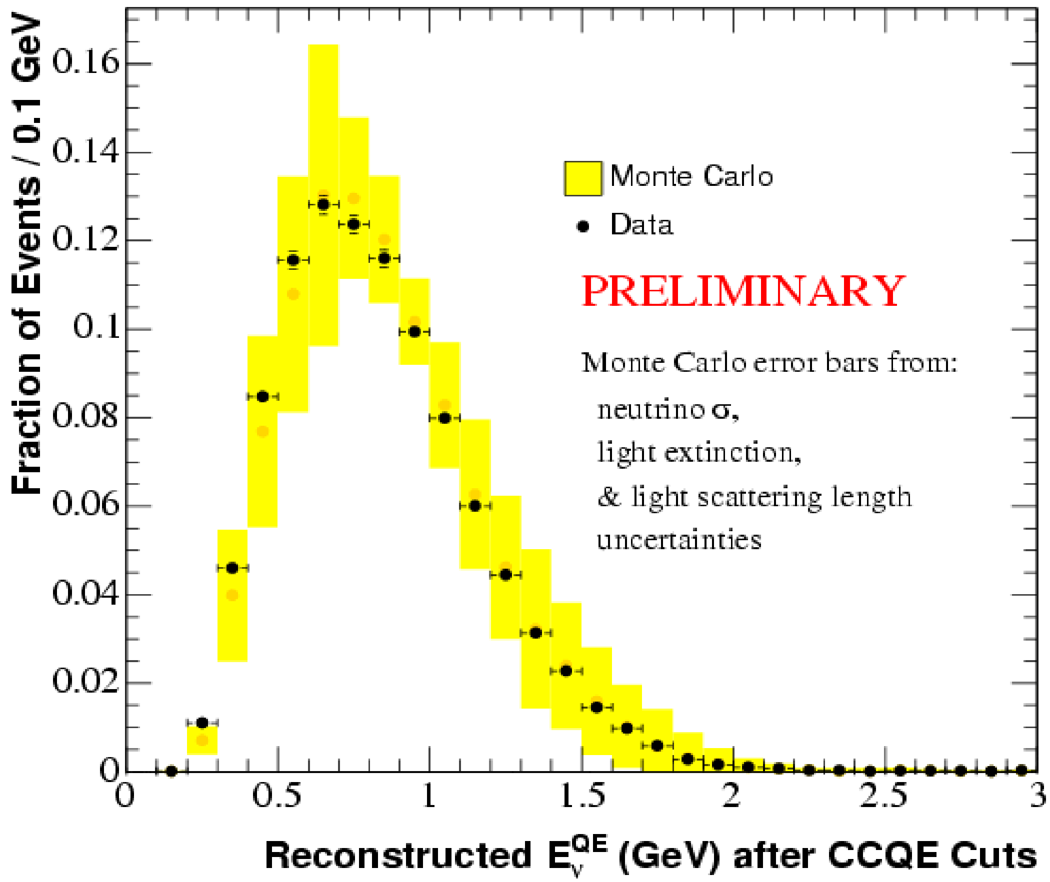
Angular resolution: 4^o at 500 MeV

Energy resolution: $5\%/\sqrt{E}$

$$E_{\nu}^{QE} = \frac{1}{2}\frac{2M_p E_\mu - m_\mu^2}{M_p - E_\mu + \sqrt{(E_\mu^2 - m_\mu^2)}\cos\theta_\mu}$$

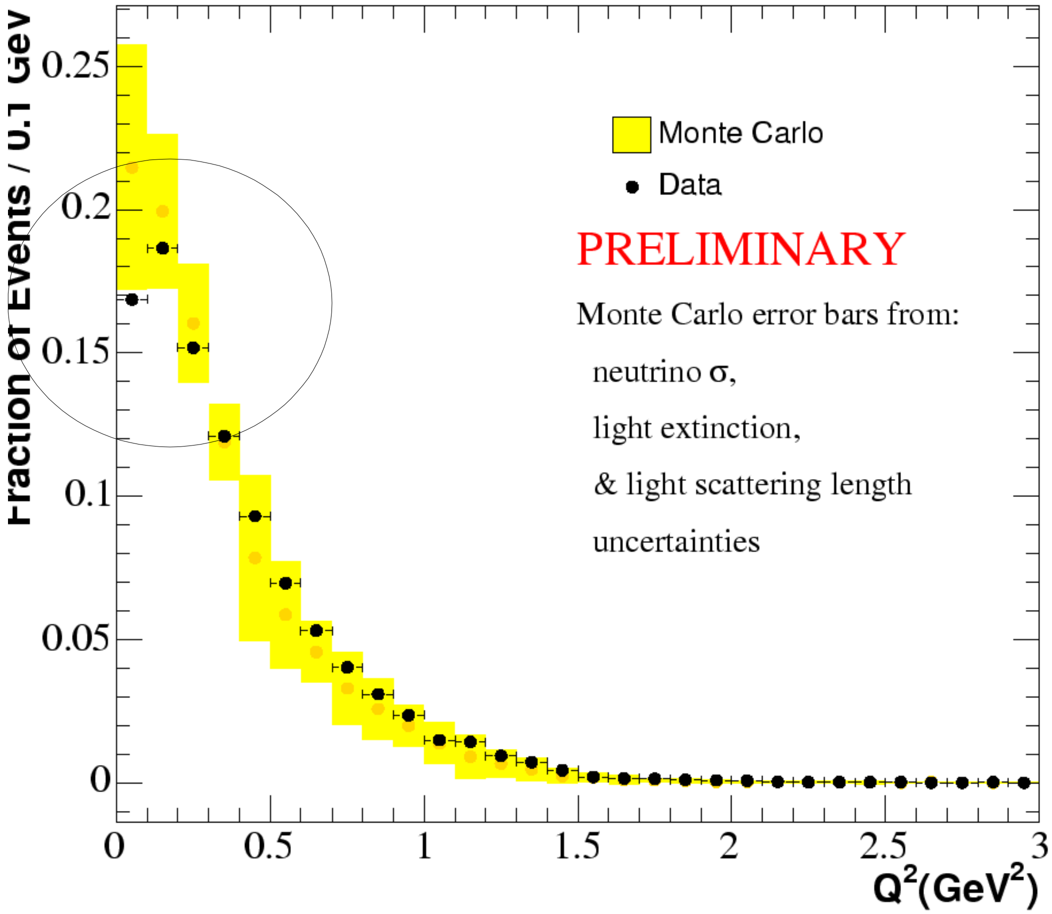


Resolution on neutrino energy ~ 10%



(relative normalization)

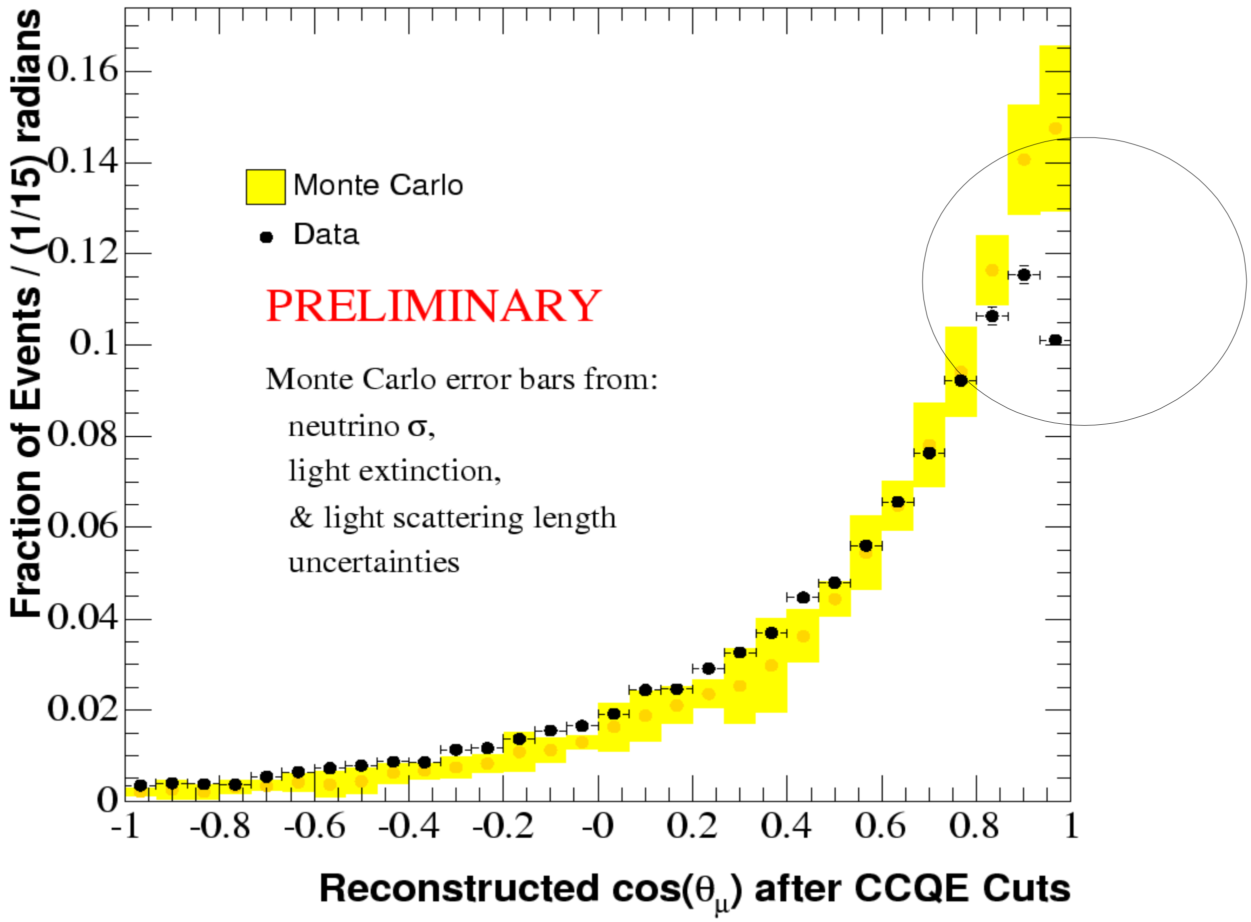
An interesting mystery at low Q^2



(Note:
Flux systematics
~10%)

Since these are QE events: $Q^2 = 2M\nu$

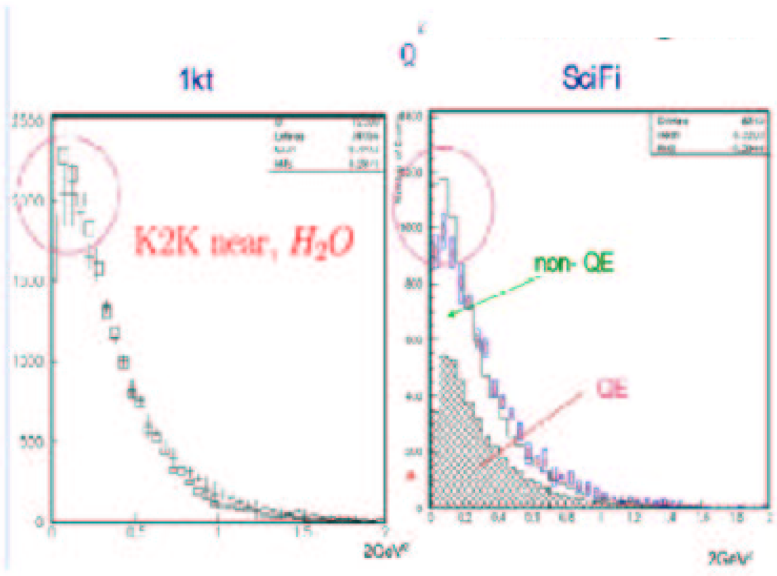
Deficit is seen much more clearly in scattering angle,
(low angle is low Q^2)

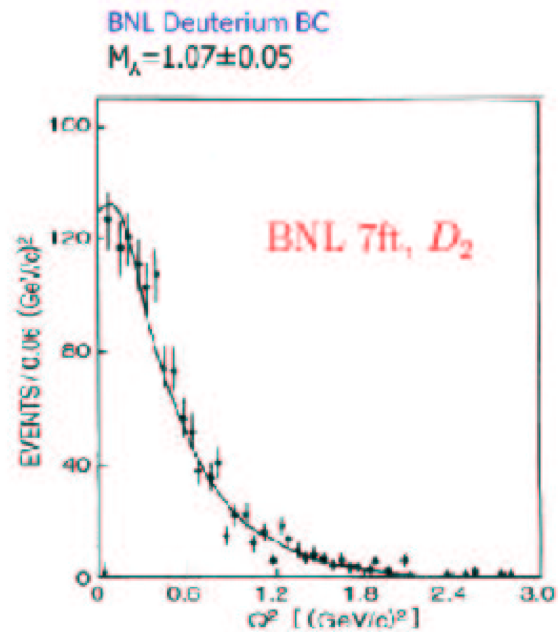


Returning to expressing this as Q^2, the suppression is...

Also observed at K2K...

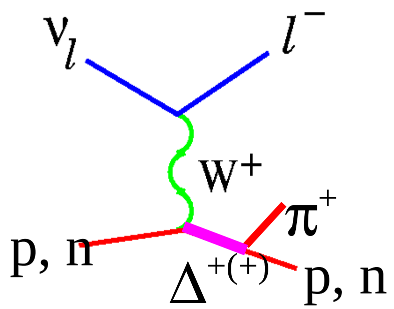
...but less obvious at BNL

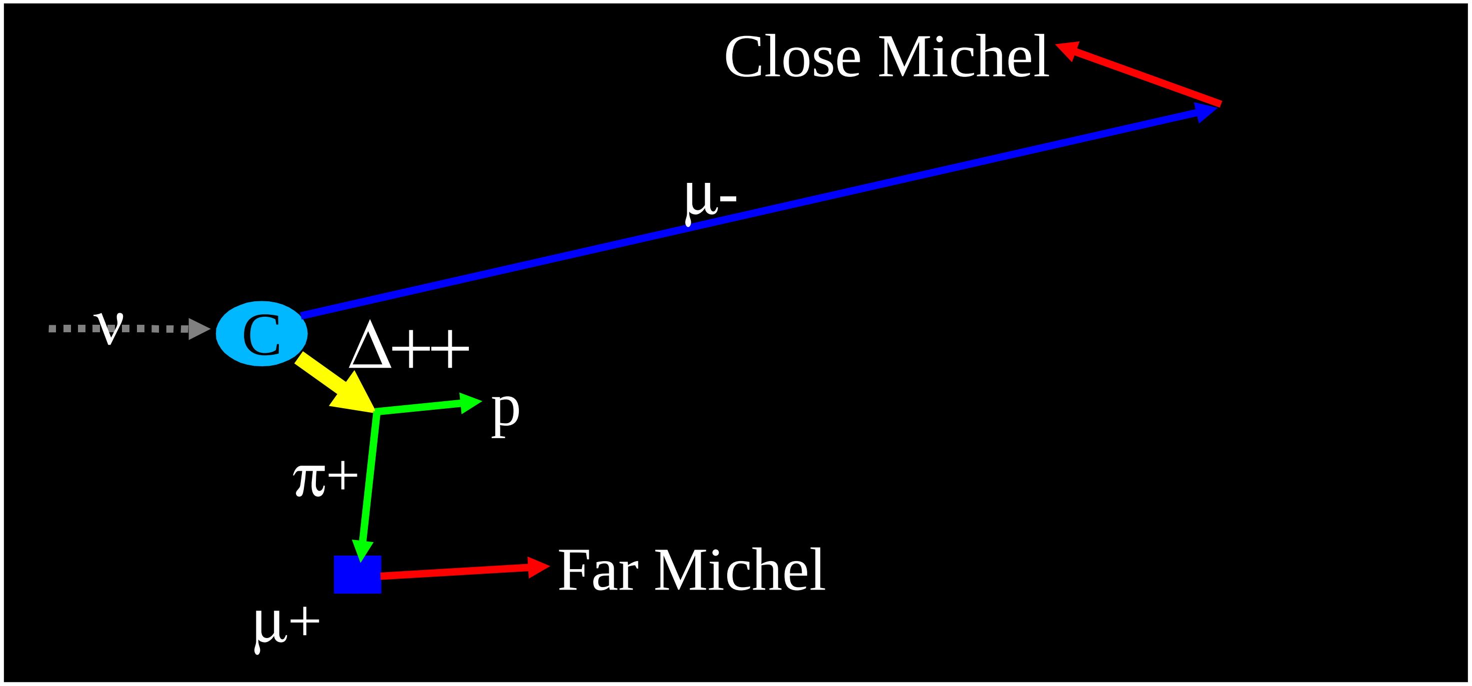




- A nuclear effect (but too large to be explained by Pauli Blocking) (We use the Fermi Gas model & are pursuing other nuclear models)
- Could be the form factor ... *We will present a measurement soon!*
- Ideas welcome!

CCPI+ Events in the MiniBooNE Detector:





- 2 muons (identified by the michel electrons)
  (one above cerenkov threshold)
- and <6 events in the veto

* 84% CCPI purity

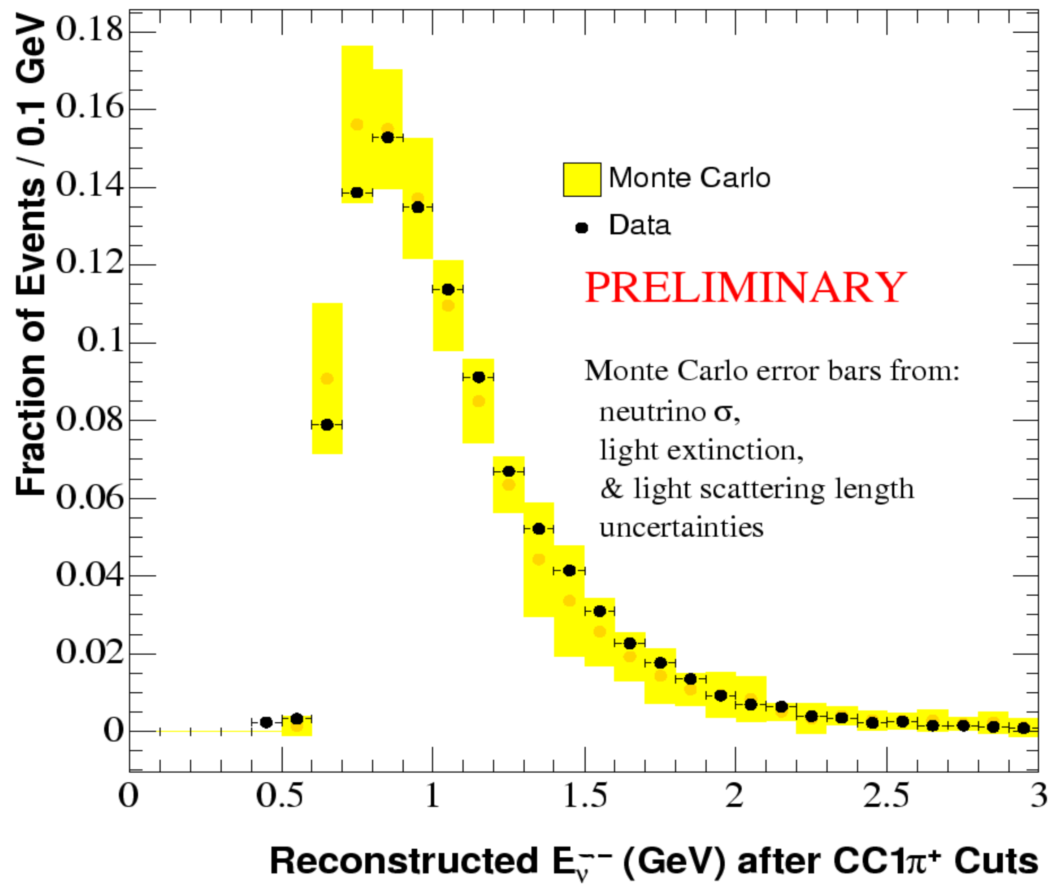
* dominant background:
multipi events

CCPI+ has
nearly the same
neutrino energy
formula as CCQE!

$$E_{\nu} = \frac{1}{2}\frac{2M_{p}E_{\mu} - m_{\mu}^{2} + (m_{\Delta}^{2} - m_{P}^{2})}{M_{p} - E_{\mu} + \sqrt{(E_{\mu}^{2} - m_{\mu}^{2})}\cos\theta_{\mu}}$$

__Neutrino Energy Reconstruction__

- Assume 2 body kinematics
  (as in CCQE)
- Assume Δ(1232) in final state
  (instead of a proton as in CCQE)
- ~20% resolution
  (largely due to Δ width)

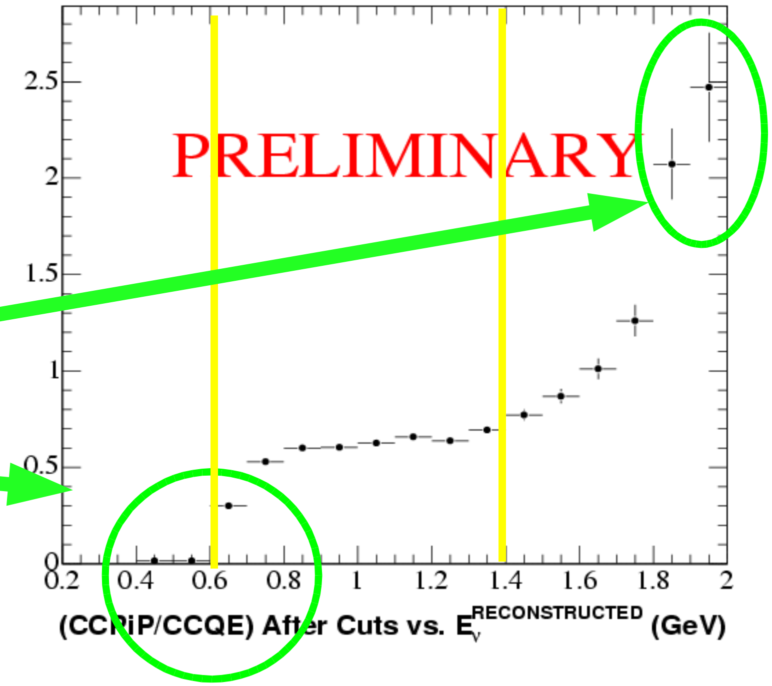


But not quite the same acceptance as CCQE...

CC1π^+/CCQE Ratio

N(CCPI+)/N(CCQE) vs. E_ν^{QE}

- CCQE cut efficiency degrades at high E due to exiting μ^-
  - CC1π^+ threshold > CCQE



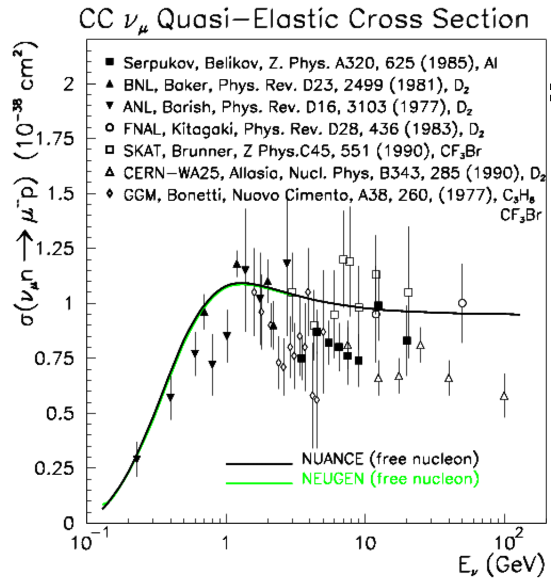
- Many errors are reduced or cancel in the ratio

- Systematic errors:
  - ν cross sections/nuclear effects in MC (~15%),
  - photon atten. and scatt. lengths in oil (~20%),
  - energy scale (~10%)

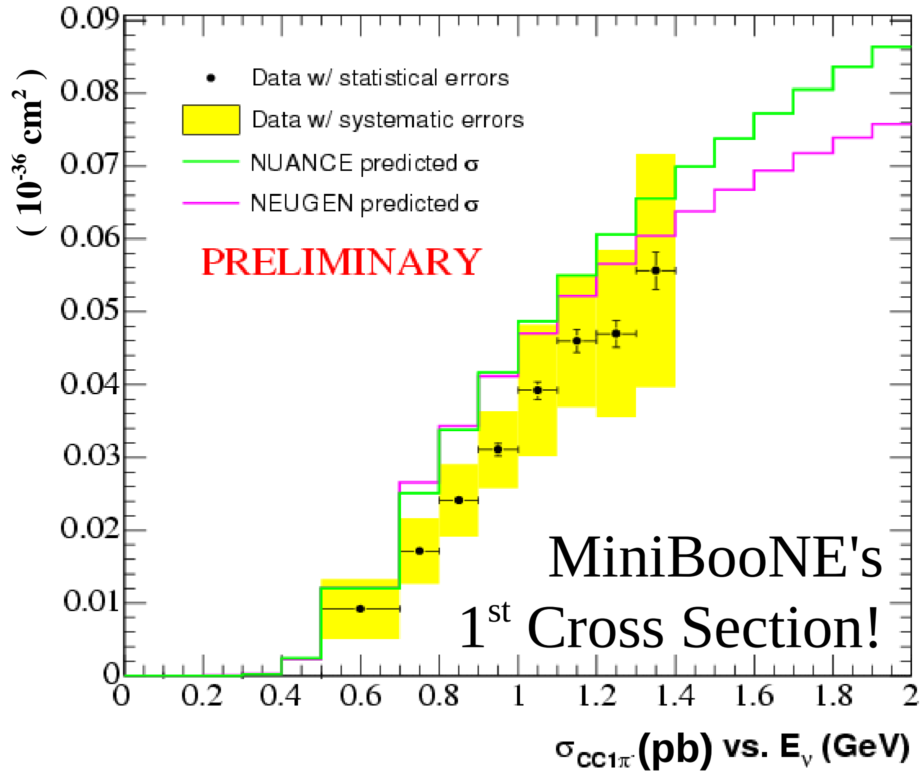
Range of similar acceptances

Take the CCPI+/CCQE ratio
Normalize it using a standard
CCQE Cross section (Nuance)

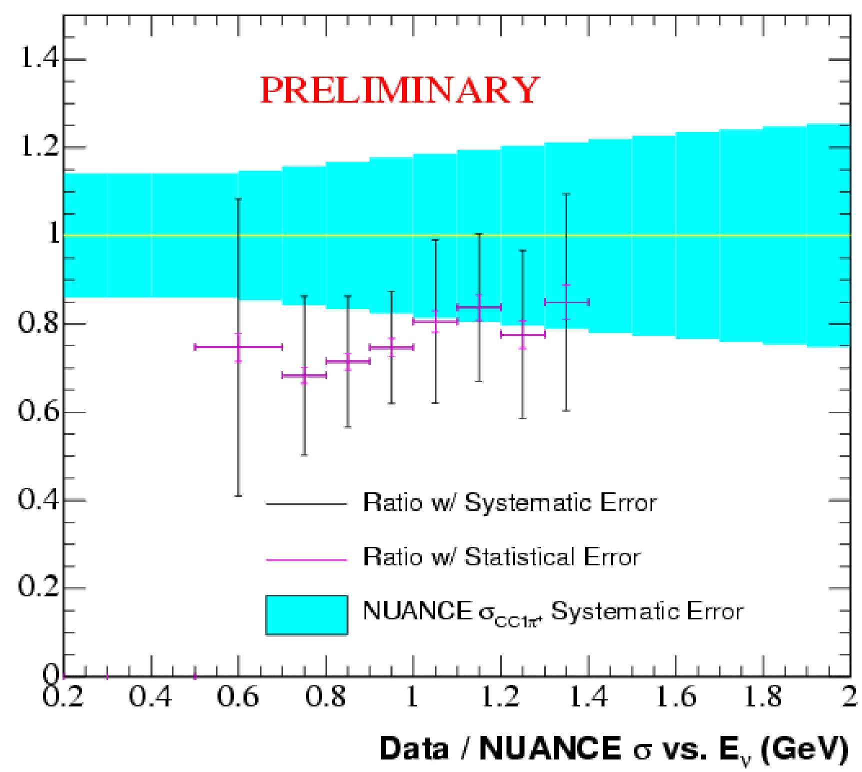
To get...



S. Zeller

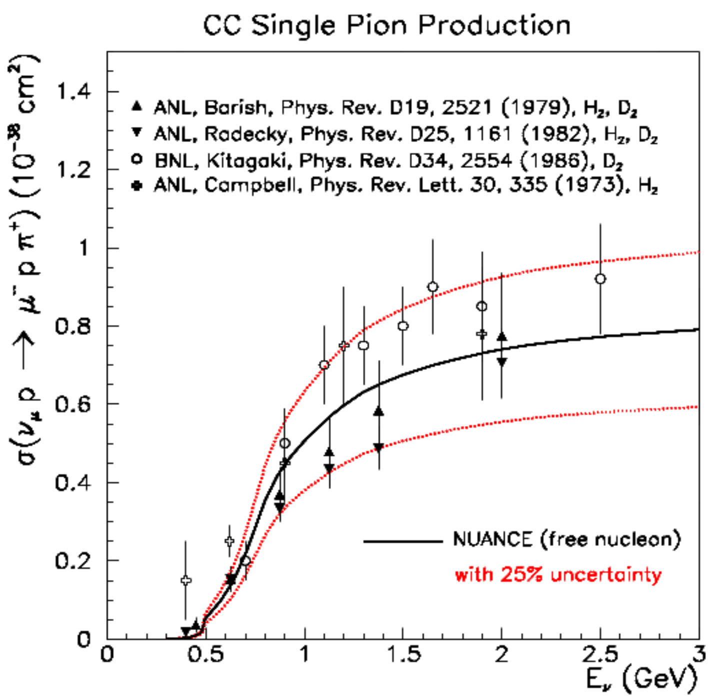


M. Wascko



NUANCE (and others) are splitting a difference between 2 past experiments

- ANL and BNL results disagree
- in normalization
- MiniBooNE result is more consistent with ANL



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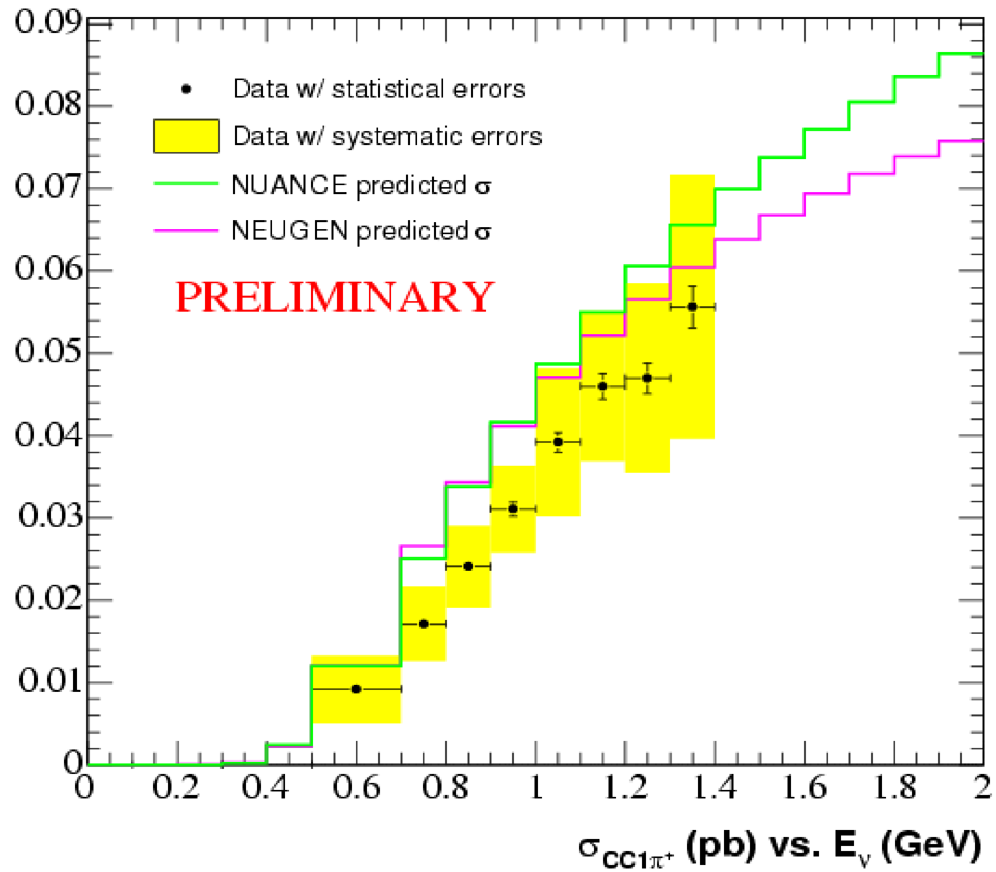
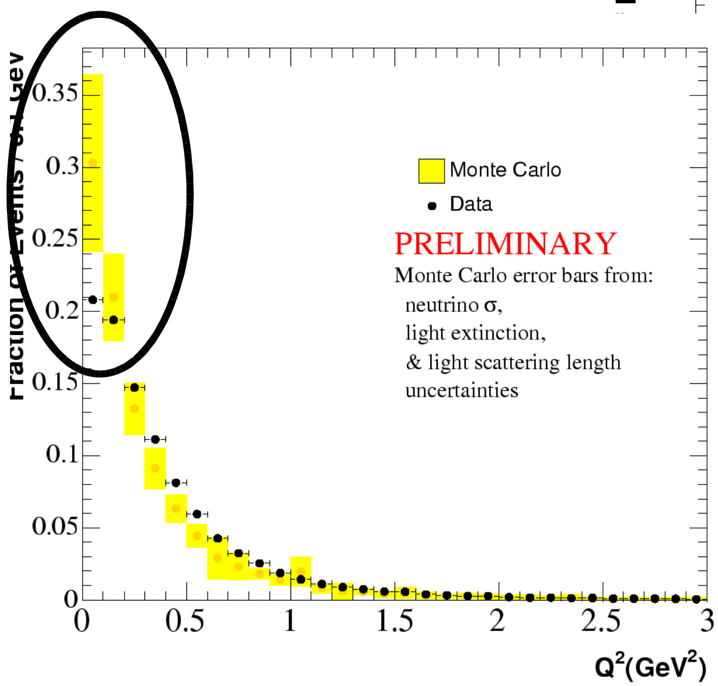
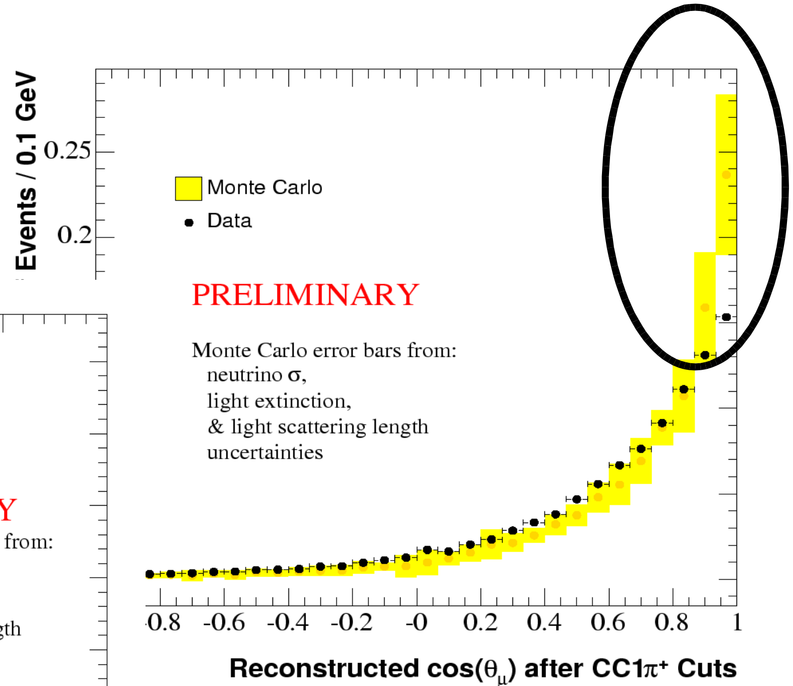


Similar interesting mystery at low scattering angles (small Q^2)

(Note:
Flux systematics~10%)





~10% different in size from the CCQE

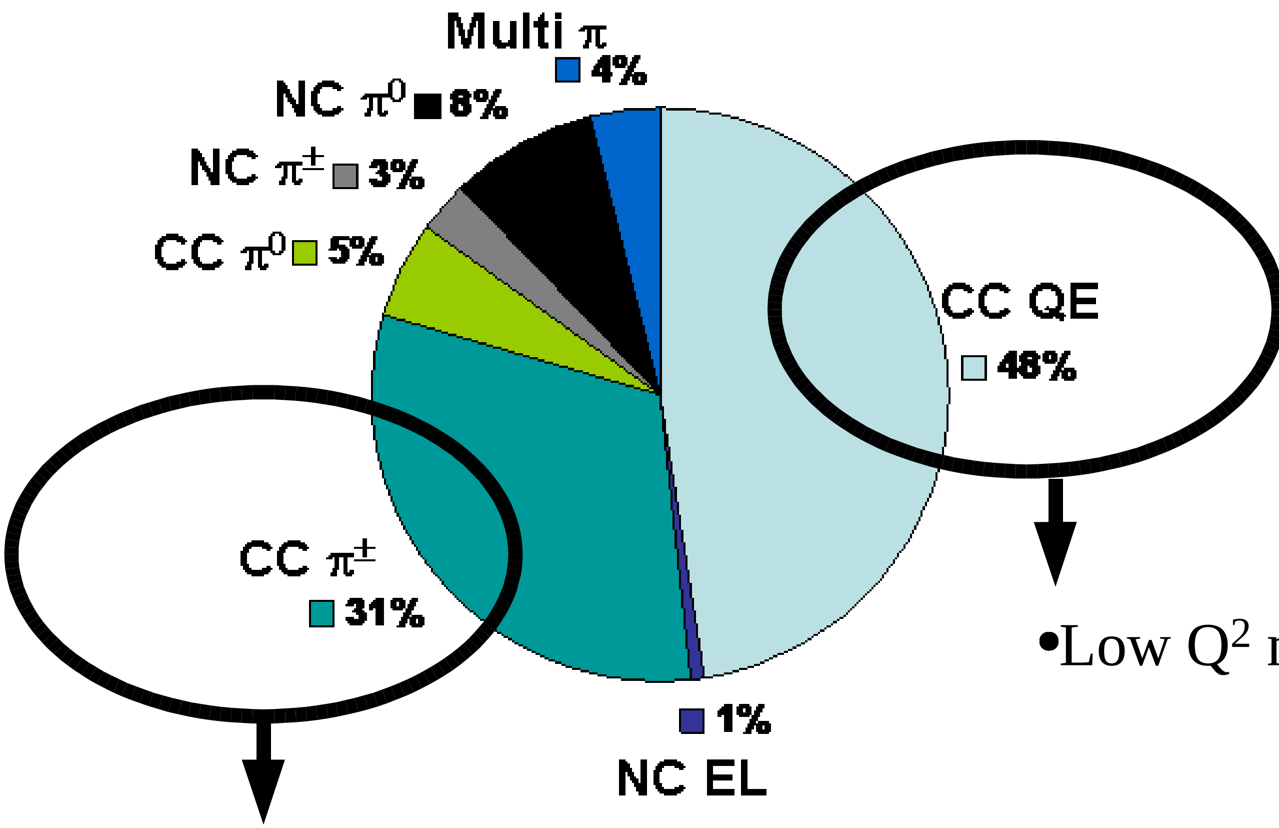
Consistent with "CCQE effect" plus less coherent scattering than predicted

More ideas welcome!

Next on CCPI+ Agenda: Coherent/Resonant ratio studies

Summary:

★ MiniBooNE is bringing out first CC Cross Section Results



•Low Q^2 mystery

•New CCPI+/CCQE ratio favors a ~20% lower CCPI+ cross section
•A low Q^2 mystery here too...